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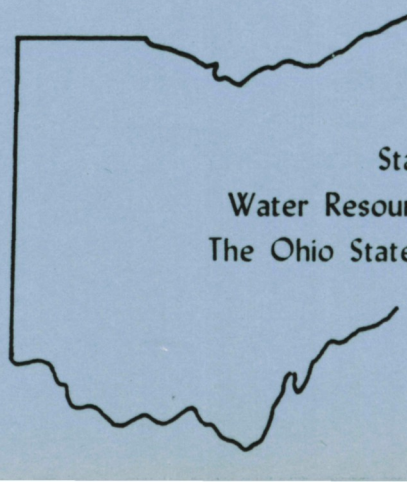
Report No. G-1037-01

FISCAL YEAR 1985 PROGRAM REPORT

Robert C. Stiefel
Director

United States
Geological Survey



State of Ohio
Water Resources Center
The Ohio State University

Report No.
G 1037-01

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Geological Survey

by

Water Resources Center
The Ohio State University
Columbus, Ohio 43210

Robert C. Stiefel, Director

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ABSTRACT

Water is one of Ohio's most important natural resources, and the State has an adequate supply to meet its immediate needs. Most of Ohio's water problems are associated with water quality. Of primary concern are the sediments, nutrients and acids in the surface waters from urban, agricultural and mining areas, and the toxic and hazardous waters that threaten the ground and surface waters. The focus of the 1985 State Water Research Program was directed at some of these needs. One project examined the simultaneous adsorption and biodegradation that occurs in a three-phase fluidized bed that utilizes immobilized living microorganisms in an aerobic wastewater treatment process. Another project studied the specific mechanisms that certain bacteria have developed to resist inhibition caused by Cadmium in the environment and to investigate the potential that these organisms have in the translocation of this highly toxic metal. A third project will develop a method to determine the impact that seasonal water usage has on the safe yield that can be provided from reservoirs used to supply municipal drinking water. The fourth project is an analysis of the risks and benefits that occur from disposing of oil and gas brines by injecting them in the annulus of producing oil and gas wells in the state. The Center's technology transfer program has produced a directory of the organizations in Ohio that have an important role in managing, protecting and conserving this invaluable natural resource. Training was provided through this program for twelve students enrolled in five disciplines at two universities in the State.

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WATER PROBLEMS AND ISSUES OF OHIO

Water is one of Ohio's most important natural resources. Bounded on the north by Lake Erie and on the south by the Ohio River and containing other extensive ground and surface waters, Ohio has an adequate supply of water to meet its immediate needs. However, the combination of large, heavily industrialized urban centers; extensive agricultural activities; high volume coal production and large coal reserves; and the associated demands for new energy production continues to cause concerns related to water quality and water management. In addition, extreme hydrologic events cause localized problems of both excessive water and water deficiencies at times.

Surface Water

The northern twenty-five percent of Ohio's area drains into Lake Erie, while the southern portion drains into the Ohio River. Runoff from Ohio's streams and rivers averages about 25 billion gallons per day. The state also receives nearly a billion gallons of runoff daily which drains through the Maumee River to Lake Erie from the neighboring state of Indiana; and Ohio has access to additional flows past its boundaries in Lake Erie and the Ohio River that total well over 150 billion gallons of water per day.

Last year, over 16 billion gallons of water were withdrawn from Ohio's surface sources each day to meet the demands for municipal supplies; rural needs for domestic and livestock purposes; irrigation; and self-

supplied industrial needs including cooling water for thermo-electric power generation. These demands account for only 60 percent of the available surface waters in the state's streams each day, and localized shortages only develop during certain dry seasons and periodic droughts.

The combined length of all the streams in Ohio approaches 44,000 miles, which means that there is approximately one mile of stream for each square mile of surface area in the state. In addition, there are more than 50,000 lakes, ponds, and reservoirs within the state having a combined surface area of 200,000 acres. Only a small fraction of these, about 6,700 acres, occur naturally. The remainder are man-made impoundments that range in size from small farm ponds to large multipurpose reservoirs.

The reservoirs in the state are used to provide water for many different purposes including municipal, agricultural and industrial supplies; stream flow augmentation; flood control; and recreation. No impoundments in Ohio, other than those on the main stem of the Ohio River, provide water for downstream navigation or hydro-electric power generation. However, there is extensive navigation on both Lake Erie and the Ohio River, and consideration is being given to the installation of low-head hydro-electric generators at several developed dam sites throughout the state.

Flooding, still a major problem in Ohio, affects both urban and agricultural areas; and it has been estimated that nearly two million acres of land in Ohio are flood prone. This represents over seven

percent of the total area of the state and includes nearly four percent of those areas classified as urban regions. Average annual flood damages in Ohio vary from year-to-year, but amount to several millions of dollars annually.

Ground Water

Ground water is an important part of Ohio's water resources. Ground water underlies most of the state but is predominate in the glacial drift in the northwest, in the ice-contact and outwash deposits in river valleys along the border of the glaciated areas, and in the bedrock of the western portions of the state. Ground water supplies are largest in the glacial valley-train deposits in those drainage basins which border the Ohio River including the Ohio, Miami, Little Miami, Scioto, Hocking and Muskingum Rivers. Well yields from these deposits often exceed 500 gallons per minute (gpm), while aquifers in the glacial drift in the northwest and west-central parts of the state produce yields between 100 and 500 gpm. Isolated aquifers in the northeast, northwest and southwest have yields between 25 and 200 gpm, while much of the northeast contains aquifers whose yield is between 5 and 25 gpm. With the exception of the valleys along the major streams, most of the aquifers in the area that is tributary to the Ohio River have yields less than 5 gpm.

Three-quarters of Ohio's 650 public water supply systems use ground water as their source. In terms of volume withdrawn, however, a lesser share of these supplies comes from ground water, for only around a half billion gallons of ground water are withdrawn each day for public water

supply purposes, while over one billion gallons come from surface water sources. However, ground water supplies nearly 80 percent of the rural water needs in Ohio, 32 percent of the irrigation waters and 21 percent of the industrial water demands. Nearly one billion gallons of ground water are withdrawn in the state each day to meet these needs.

Water Quality

It is the quality of water, rather than its quantity, that is the more critical and limiting condition associated with the use of both ground and surface waters in Ohio. The ground waters of the state frequently have relatively high, natural mineral contents; but, except for a few local areas, most of these waters are free from man-related contamination. Most complaints are related to increased levels of turbidity, bacterial populations and other substances from improperly sited or poorly constructed or maintained wells. Other problems are related to the spillage and leakage of brines and petroleum at oil wells in the southeastern part of the state; the mis-application of pesticides, herbicides and insecticides in agricultural areas; and the improper siting and operation of solid and liquid waste disposal facilities. Some minor ground water problems associated with the excessive use of highway de-icing salts or its improper storage have also been reported.

The dissolved solids concentrations in Ohio's streams range between 120 and 2,500 milligrams per liter (mg/ℓ). The higher concentrations are found in the Tuscarawas, Cuyahoga and Grand Rivers and in other stream reaches below major municipal and industrial outfalls or in areas subjected to diffuse source runoff.

Of the 23,000 miles of the principal rivers downstream of major urban areas in the state that have been monitored, 16,000 miles, or 70 per cent of these streams, meet the current water quality standards. Where problems do exist, they are frequently caused by inadequate municipal wastewater treatment at facilities that need to be upgraded or expanded, or by combined sewer overflows. Substantial improvements in surface water quality have resulted from the development of pretreatment regulations for industrial waste discharges to municipal sewerage systems. Violations of the state's water quality standards occur most often in dissolved oxygen levels; ammonia nitrogen concentrations; the numbers of fecal coliforms; and the levels of heavy metals such as lead, zinc, and cadmium.

Acid mine drainage is a major cause of water quality problems throughout the Appalachian Coal Basin in the eastern United States. In Ohio this region extends in a band approximately 50 miles wide in a southwesterly direction from the east-central to the south-central parts of the state. Acid drainage from abandoned and improperly operated or reclaimed coal mined lands causes a loss of water for domestic and industrial uses; the degradation of water quality for recreational purposes; a lethal impact on the aquatic life in a stream;

and, an accelerated deterioration of highway and railroad bridges and electrical trasmission lines and towers. Drainage from abandoned coal mines, both surface and underground, has impacted around 1,500 miles of streams in 27 counties in southeastern Ohio. Approximately 370,000 acreas of abandoned strip mines, 7,000 acres of coal refuse piles and 3,000 underground mines are contributing to this problem. It has been estimated that four billion dollars would be needed to reclaim the abandoned mines and refuse piles throughout Ohio. Projected revenues from severance taxes earmarked for abandoned mine reclamation come to about ten million dollars annually. Obviously, the technologic problems and the economic costs associated with the control of acid mine drainage will continue to keep this a major problem of water quality in southeastern Ohio for years to come.

Little detailed information is available concerning the impacts that diffuse sources of pollution such as agricultural and urban stormwater drainage have on the quality of water in Ohio's inland streams. One concern with non-point pollution is the sediment that is dislodged from the land surface and carried to the streams. Of greater concern are the pollutants, such as the nutrients, heavy metals and toxic organic substances, that enter the streams attached to the sediments. No need for intensive, non-point source control programs to meet water quality standards in that area of the state that drains to the Ohio River has been shown; but several studies are underway in the Lake Erie drainage basin to define the role of agricultural drainage on the water quality in Lake Erie. Much more research and many more demonstration projects on the best management practices for agriculture, silviculture, mining

and urban runoff control must be conducted before this problem is fully understood and control measures can be instituted.

The trophic status of several lakes and reservoirs has been studied; and results to date suggest that the lakes and reservoirs in the sandstone bedrock areas of the state have generally lower trophic levels than those in the limestone bedrock areas or glaciated regions. Water quality was generally good to excellent in most of the lakes and reservoirs surveyed. However, excessive concentrations of copper and other heavy metals, bacteria and other pollutants normally associated with urban activities were identified in some of the lakes.

Recent studies on Lake Erie indicate that there has been a reduction in several key pollutants and a gradual, but steady, improvement in the water quality in the Lake during the past few years. Phosphorus is a major pollutant which results in the excessive growth of algae and other aquatic plants. As these plants die and decay, they deplete the oxygen resources of the Lake. The construction of facilities to remove phosphorus at those municipal wastewater treatment plants which discharge phosphorus at those municipal wastewater treatment plants which discharge directly to Lake Erie has been a major factor in the reduction of loadings and of the subsequent reduction of the anoxic areas within the Lake. Additional work on the control of phosphorus from both diffuse sources and point sources needs to be accomplished, but a significant start has been made.

Levels of bacteria have been reduced in the nearshore zones where municipal wastewater treatment facilities have been constructed. This

has permitted regulatory agencies to re-open bathing beaches which were often closed during the period between 1960 and 1970. Concentrations of mercury and pesticides have been reduced substantially, principally because of the federal bans that have been instituted on their manufacture, use and disposal. PCB remains a major challenge, as does the control of sediment and the nutrients, fertilizers and organic chemicals that are attached to it.

Fish populations, including the walleye pike, are beginning to increase again in the lake; but the quality and diversity of fish is still far from what they were in the past. Thermal pollution is a localized problem in some near-shore areas. However, as closed cycle cooling is required on all power generation facilities, the extent of this problem will diminish.

PROGRAM GOALS AND PRIORITIES

The Water Resources Center at The Ohio State University encourages and supports research that is directed at providing information needed to solve the major water problems at the local, state, regional and national levels. The research program at the Center includes basic or fundamental research, problem oriented or applied research, and information dissemination and technology transfer activities.

During FY 1982, the Center, in cooperation with several groups of water-related agencies and officials throughout the State prepared a prioritized list of Ohio's major water resources problems. Based upon this analysis, the following ranking of these problems was developed:

1. POLLUTION FROM DIFFUSE SOURCES - including agricultural runoff; urban runoff; runoff from on-site waste disposal systems; runoff from active, reclaimed or abandoned coal and strip mines.

2. CONTAMINATION OF DRINKING WATER SUPPLIES - including surface and groundwaters for both urban and rural uses by diffuse and point sources, and by the disposal of toxic and hazardous wastes on the land.

3. TOXIC AND HAZARDOUS WASTE DISPOSAL - including their control, treatment, disposal and impact upon land, water and air resources.

4. POLLUTION FROM POINT SOURCES - including municipal and industrial sources not yet in compliance with their NPDES permits.

5. IMPACTS OF FLOODING AND DRAINAGE - including flood damages, the use of flood plains and alternative structural and non-structural means of controlling floods and reducing flood damages.

6. IMPACTS OF WATER RESOURCES DEVELOPMENTS - including the impacts on various land uses caused by structural and non-structural water resources developments such as the extension of water mains and sewers into rural areas; flood control projects; hydro-electric power generation; water-based recreation; etc.

7. INSTREAM FLOW NEEDS - including interrelationships among water quality, water quantity and land use practices on the instream flow needs for fish, wildlife, and recreation on the optimum development and protection of these instream uses.

8. IMPACTS OF SYNTHETIC FUEL DEVELOPMENT -including requirements for water and impacts of the disposal of wastes from these processes into waters and onto the land.

9. IMPACTS OF ATMOSPHERIC POLLUTION - including the effects of acid precipitation and atmospheric fallout on water quality and the environment.

10. ALLOCATION OF WATER RESOURCES - including the development of contingency plans for the allocation and conservation of limited water supplies among competing water users during period of low stream flows.

Subsequently, the Directors of the Water Resources Research Institutes in the Great Lakes, Upper Mississippi and Ohio River Basin's met to identify from their State problems the major water resources research priorities for the Region. These priorities are included at the end of this section of this Report.

The focus of the 1985 State Water Resources Research Program was primarily directed at some of these critical needs and at some of the State's water management problems.

The project by L. S. Fan entitled "Simultaneous Adsorption and Biodegradation in a Three-Phase Fluidized Bed with Immobilized Living Cells for Aerobic Wastewater Treatment" contributed to the knowledge of the intrinsic rate of biodegradation that can be developed in a biofilm that contained immobilized, living cells and explored the simultaneous effects that adsorption and desorption had on the overall biodegradation rate in the biofloc. This wastewater treament process is felt to be a substantial evolution in the operational technology of bioreactor design; and the successful completion of this project could result in the development of an innovative, reliable and considerably less costly wastewater treatment system.

The project entitled "Cadmium Assimilation by Lake Sediment Bacteria" studied the specific mechanisms that certain sediment bacteria have developed to resist inhibition by Cadmium and determined the potential role that these organisms have in the translocation of this highly toxic metal in the environment. Information obtained on the bacterial strain isolated during this study will aid in the development of

genetically engineered bacteria for the treatment of wastewater containing high levels of Cadmium and other toxic metals.

The project entitled "Effect of Seasonal Water Usage Variations Upon Reservoir Safe Yield", will characterize the seasonal fluctuations in the demand for water in community water systems and will develop a methodology to determine the effect that these variations have on the calculation of the safe yield that can be provided from a surface water supply.

The project by Drs. Hobbs and Haimes entitled "Risk-Benefit Analysis of Annular Disposal of Oil and Gas Brines" examined the risks and the benefits of this method of brine disposal and compared it with deep well injection. Ohio is the only state which still permits the controversial practice of disposing of oil and gas well brines by injecting them back into the annulus of the production well. Recent legislation permitting annular disposal in Ohio will probably be reviewed in the next few years, and the results of this study could affect the decision to continue the practice of annular brine disposal.

Training on these research projects was provided to a post-Ph.D. student, two doctoral students, and five graduate students in the disciplines of Chemical Engineering, Water Resources Engineering, Water Resources Systems Engineering and Environmental Microbiology/Microbial Physiology. In addition, four undergraduate students gained practical knowledge and experience by working on these projects.

The technology transfer program of the Water Resources Center produced the Directory of Ohio's Water Management Associations and Organizations, continued the bi-monthly luncheon seminar programs; provided support to the Water Resources Center library; distributed project reports of research projects performed at the Center; and, provided opportunities to consult and collaborate with the States leading water resources officials.

Training was provided to twelve students in five disciplines at the two universities in the State that participated in the FY 1985 program.

REGIONAL RESEARCH PRIORITIES

Great Lakes - Upper Mississippi - Ohio River Basin

1. GROUNDWATER CONTAMINATION - tracks pollutants through the vadose zone to the groundwater and determine their rate of dissipation in the aquifer; assess the impacts of the disposal of municipal and industrial wastes and effluents on groundwater systems; evaluates sources of recharge of the principal aquifers in the region; determines the effects of the storage of waste heat in aquifers on groundwater quality.

2. POLLUTION OF LAKES AND STREAMS FROM NON-POINT SOURCES - Assess relative effectiveness of non-point pollution control "best management practices" to meet the demands of P. L. 92-500; Evaluates the effects of atmospheric fallout and precipitation (acids, toxic metals and hazardous trace organic) on public health and the aquatic environment; estimates the effects of drainage from land use activities in urban areas on surface water quality; models sediment transport processes and devises techniques for determining sediment delivery ratios; determines the relative effectiveness of voluntary programs enhanced by various incentives and regulation as mechanisms of implementing non-point pollution control; predicts the impacts that new agricultural technologies will have on surface and groundwater resources.

3. ADVERSE WATER RESOURCES IMPACTS OF ENERGY PRODUCTION AND MINING - evaluates the impacts that drainage from mining activities will have on the incursion of acids, toxic metals, radio nuclides and hazardous organic compounds into the environment; assess legal, economic, environmental and social impacts and develops means for resolving water user conflicts associated with siting, constructing and operating energy conversion facilities and mining operations; assess legal, economic, environmental and social impacts and develop means for resolving water user conflicts associated with siting, constructing and operating energy conversion facilities and mining operations; examines the potential benefits, public and environmental, from the reclamation of heated waters from power generation.

4. POTENTIAL INSUFFICIENCY OF WATERS FOR AGRICULTURE AND RURAL COMMUNITIES - determines optimal water requirements for crop production and develop practical methods for irrigation scheduling; evaluates criteria for establishing minimum requirments for the drainage of imperfectly drained soils of the region; develops water conservation practices and methods for holding and temporarily storing surface and drainage waters for reuse in periods of seasonal suboptimal precipitation.

5. LOSS AND DEGRADATION OF WATER BASED FISH AND WILDLIFE HABITAT - defines the functional and economic value of wetlands including ecological and hydrological mechanisms that influence their integrity; develops acceptable mechanisms, including incentives

and legislation, for preserving publicity and privately owned wetlands; determines the quality and quantity of instream flow necessary to maintain an active and viable aquatic biota; determines the potential and incentives needed to increase wildlife and waterfowl production on private lands.

6. MISCELLANEOUS - Develops the relationship between commercial/commodity and recreational use of the major lake and river systems of the region. Research emphasis should be placed on development of sufficient water-based recreational facilities in urban settings.

SYNOPSIS

Project No. 02 Start: 07/85 (actual)
End: 06/86 (expected)

Title: Simultaneous Adsorption and Biodegradation in a Three-Phase Fluidized Bed with Immobilized Living Cells for Aerobic Wastewater Treatment

Investigators: Fan, Liang-Shih, The Ohio State University, Columbus

COWRR: 05D Congressional District: Fifteenth

Descriptors: fluidized bed process, biological wastewater treatment, phenols, draft tube, kinetics, adsorption

Problem and research objectives:

Fluidized bed bioreactors have been demonstrated to be more cost-effective and efficient in wastewater biological treatment than conventional treatment systems such as trickling filters, activated sludge systems, and rotating drum contactors. Coupling the traditional physical removal process such as adsorption with biological degradation process also has been shown to enhance the treatment effectiveness. The fundamental transport and kinetic behavior of the coupling adsorption and biodegradation process in a three-phase fluidized bed bioreactor, however, has been little studied. The objective of this study is to develop an understanding of the intrinsic characteristics of the interaction between the adsorption/desorption of biodegradable pollutants by activated carbon particles and the biodegradation kinetics of the biofilms adhered to the surface of the activated carbon particles. Phenolic compounds, which are the major pollutants in the wastewater discharged from coal conversion processes and are under strict regulation by the USEPA on its content in surface

water, were selected as the model biodegradable pollutants in this study. The relative merits of the adsorption/desorption and biodegradation to the overall phenol removal rates was also evaluated.

Methodology:

Activated carbon particles were immobilized with cells of a mixed culture and operated for phenol removal in a draft tube three-phase fluidized bed bioreactor (DTFB) for a period of 1 to 3 months. The activated carbon particles were then withdrawn from the DTFB for adsorption and diffusivity experiments. In the adsorption experiments, the attached biofilms were completely removed from the activated carbon particles, and washed to desorb any residual phenol. These particles were then placed in a well-stirred vessel containing solution of phenol at a known concentration to study the adsorption equilibrium isotherm. In the diffusivity experiments, bioparticles (activated carbon particles attached with biofilm) were inactivated with $HgCl_2$, washed to desorb residual phenol, and then placed in a well-stirred vessel containing phenol solutions. The variation of phenol concentration in the solution with time was monitored and the data were fitted into mass balance equations to evaluate the diffusivity of phenol within the biofilms of different densities.

In the transient phenol degradation experiments in the DTFB, a step increase in influent phenol concentration was introduced into the DTFB originally in steady state and the change of bulk phenol concentration with time was monitored.

Principle findings and significance:

The phenol adsorption isotherm of the spent activated carbon particles was found to be approximately invariant with time after they had been used in the DTFB for more than one month. The adsorption of phenol in the spent carbon particles was substantially reversible and the adsorption capacity was approximately half of that of virgin carbon particles. The decrease in adsorption capacity in the spent carbon particles presumably is caused by irreversible binding of some metabolites excreted by biomass in biofilms to part of the interior surface of carbon particles. Langmuir adsorption isotherm equation fitted experimental data satisfactorily.

The diffusivity of phenol within the biofilms of different dry densities was evaluated by both steady state biofilm kinetic model and transient concentration decay experiments using inactivated biofilms. Both results showed that the diffusivity of phenol within the biofilm is a weak function of biofilm dry density, and is approximately in the range of 10 to 25% of diffusivity of phenol in water.

When imposed with a step increase in influent concentration of phenol, the transient behavior of the DTFB biofilm system followed the same pattern as that in a suspended cell system in that a larger transient increase in bulk substrate (phenol) concentration, and the greater time required to regain a new pseudo-steady state were always observed for a larger step change made. The peaks of the transient change in bulk phenol concentration for three experimental runs already performed all occurred within less than an hour after the step change was made.

These were shorter in time than the results obtained from the suspended cell systems. It is believed that the adsorptive capacity of the activated carbon particles for phenol played an important role in helping the biofilm system stablize more quickly. The quantitative contribution of the adsorption effect will be determined from a mathematical model of the system. This model will be constructed during the second year's effort on the project.

Publications and professional presentations:

(1) Tang, W. T., and L-S Fan, "Steady State Phenol Degradation in a Draft Tube Gas-Liquid-Solid Fluidized Bed Bioreactor", AIChE J., in press (1986).

(2) Fan, L-S, K. Fujie, T-R Long, and W. T. Tang, "Characteristics of Draft Tube Gas-Liquid-Solid Fluidized Bed Bioreactor with Immobilized Living Cells for Phenol Degradation," to be presented in World Congress III of Chemical Engineering, Sept. 21-25, 1986, Tokyo, Japan.

M. S. theses:

(1) Zehner, B. J., "Diffusivity of Phenol within a Fixed Film in a Draft Tube Three-Phase Fluidized Bed Bioreactor", The Ohio State University, 1986.

(2) Tong, C. C., "Concentration Multiplicity in a Draft Tube Fluidized Bed Bioreactor Involving Two Limiting Substrates", The Ohio State University, 1986.

Ph. D. dissertations:

None

SYNOPSIS

Project No. 03 Start: 07/85 (actual)
End: 06/86 (expected)

Title: Cadmium Assimilation by Lake Sediment Bacteria

Investigators: Pfister, Robert M., The Ohio State University, Columbus

COWRR: 05B Congressional District: Fifteenth

Descriptors: cadmium assimilation, sediment bacteria, aquatic environment, Lake Erie

Problem and research objectives:

Cadmium (Cd) has long been recognized as a toxicant and more recently it has been demonstrated as a potent mutagen, carcinogen, and teratogen. There is even a specific human disease (Itai Itai disease) associated with the ingestion of Cd that has accumulated in the food supply. Yet, despite the known toxicity of this metal, Cd has been enriched to potentially dangerous levels in the environment as a result of its extensive use in the electroplating industry and in the manufacturing of a diverse group of products including paints, dyes, alloys, batteries, fungicides, rubbers, and plastics. In recent years, the problem of Cd pollution has been further magnified by the acidification of many aqueous environments and by the routine release of chelators and detergent builders in residential and industrial waste. Both acidification and elevated levels of pollutants with chelating potential can mobilize Cd and make it more available to many life forms including man.

After Cd has entered an aquatic environment, microbial assimilation of soluble Cd can result in the conversion of the soluble metal to a

particulate form. Such conversion can dramatically alter both the dynamics of Cd cycling in the environment and the availability of the metal to other life forms. Our preliminary investigations of Cd levels in sediments from Lake Erie and the Cuyahoga River indicate that Cd has been enriched in these sediments to levels that equal or exceed those found to be inhibitory to many microorganisms. Therefore, bacteria present in these sediments may have developed some mechanism of resistance to the metal. The environmental implications of the various Cd-resistance mechanisms that have been demonstrated in laboratory cultures are quite different. Consequently, the impact of Cd-enriched pollution on a sediment microbial community and the role that community plays in the translocation of Cd in the environment are dependent on the nature of the Cd-resistance mechanisms that are operating in the sediment bacterial community. The overall objective of this research is to determine the potential role of sediment bacteria in the accumulation and translocation of Cd through the sediments as a result of the specific Cd-resistance strategies adopted by these organisms.

Methodology:

Cd-enriched and comparatively Cd-free sample sites were selected based on the Cd concentrations in the top 10 cm of sediment. The Cd concentration at each site was determined using direct aspiration atomic absorption spectrophotometry of nitric acid digests prepared from the sediments. Bacteria were isolated from each site on plate count agar amended with 0, 15, or 60 ppm Cd. Each of the isolates was tentatively identified using standard microbiological techniques.

Each of the isolates was tested for resistance to copper (Cu), lead (Pb), mercury (Hg), nickle (Ni), zinc (Zn), and strontium (Sr) as well as 16 different antibiotics. Both metal and antibiotic sensitivities were determined using disc diffusion assays. The ability of each isolate to accumulate Cd was assessed using radioactive ^{109}Cd and the effects of the following treatments on Cd accumulation as compared to controls was tested for each isolate; pre-incubating cells with cyanide (CN^-), pre-incubating cells with carbonyl cyanide m-chlorophenyl hydrazone (CCCP), and incubating cells at 4°C.

The effect of Cd on respiration by each of the isolates was determined using an oxygen probe to monitor oxygen consumption in the presence and absence of Cd.

Principal Findings and Significance:

From comparatively Cd-free (<3ppm Cd) sediments, we have successfully isolated bacteria that fall into three different Cd-sensitivity groups based on their ability to grow in the presence of 0, 15 or 60 ppm Cd. We were able to obtain bacteria that were resistant to 15 and 60 ppm Cd from comparatively Cd-free sediments. This suggests that the potential to grow in relatively high concentrations of Cd exists within some members of bacterial communities that inhabit relatively Cd-free environments. Thus, Cd resistance mechanisms that might ultimately alter the deposition and migration of Cd in the sediments appear to be in place even in comparatively Cd-free sediments. Bacteria possessing Cd resistance mechanisms would most likely become predominant in the sediment community if the environment became contaminated with Cd. Our

results also demonstrate that Cd-resistance isolates tend to accumulate less Cd than Cd-sensitive isolates. Therefore, bacteria that would most likely predominate in a Cd-enriched environment would contribute less to the total Cd accumulated in the sediments than would the Cd-sensitive isolates if they were able to survive in sediments with elevated levels of the metal. In addition, we found no Gram-positive isolates capable of growth at 15 or 60 ppm Cd, whereas Gram-positive isolates were obtained on unamended media from each of the Cd-free test sites. This suggests that bacterial communities in Cd-enriched sediments may be restricted to various Gram-negative organisms that are able to limit cellular accumulation of Cd. However, our observations are limited to aerobic heterotrophic members of the bacterial sediment community and in no way exclude the possibility of the existance of Cd-resistant Gram-positive sediment bacteria or Cd-resistant bacteria in which Cd-resistance is linked to increased accumulation of the metal. However, those bacteria we have isolated and identified as Cd-resistant, are all Gram-negative and generally take up less Cd than do the Gram-negative or Gram-positive Cd-sensitive isolates from the same site.

Upon initial inspection of sensitivity testing data for isolates from Cd-free sediments, no consistant pattern was discerned that linked Cd resistance with resistance to any of the antibiotics or other metals that were tested. There did appear, however, to be a correlation between some of the isolates that demonstrated the greatest sensitivity to Cd and those isolates that were most sensitive to Zn. This suggests that Zn enrichment of sediments may inhibit the growth of at least some

of the same organisms that would be inhibited by Cd pollution. We are continuing with computer analyses of the metal and antibiotic resistance data to determine if resistance to other toxic metals or resistance to antibiotics is linked to Cd resistance in isolates from both Cd-free and Cd-enriched sediments.

As was previously stated, the group of isolates from Cd-free sites that demonstrated the greatest resistance to Cd accumulated less Cd than did the Cd-sensitive isolates. When we tested the energy dependence of Cd accumulation by pre-incubating cells of each isolate with CN^- or CCCP or by incubating cells at 4°C, no consistant response in Cd accumulation by all isolates from a single Cd-sensitivity group was apparent. The results obtained from CN^- treated cells indicate that for some isolates Cd accumulation is dependent on electron transport, whereas Cd accumulation by other isolates is unaffected or increased when electron transport is blocked by CN^-. Similar results were obtained using the uncoupler CCCP in that Cd accumulation by some isolates was decreased by pre-incubation of cells with CCCP. Cd accumulation by cells at 4°C also varied with some cells demonstrating decreased accumulation of the metal at the reduced temperature, whereas other isolates were unaffected or showed increased accumulation of the metal at 4°C. None of the possible responses to each of the treatments discussed above was restricted to isolates from a single sensitivity group. Therefore, the effect that these treatments had on Cd accumulation by an individual isolate could not be used to predict the sensitivity of the isolate to Cd.

All of the isolates from the three different sensitivity groups were not capable of growth under strictly anaerobic conditions. This fact, together with the lack of uniformity in response to the various inhibitors within a given sensitivity group, suggests the possibility that the differences in Cd resistance between each sensitivity group may not reside in the energy producing systems of Cd-sensitive and Cd-resistant bacteria. To test this hypothesis, the effect of Cd on respiration by each of the isolates was tested. Our results indicate that the sensitivity of the respiratory chain of each isolate to Cd is not the single determining factor that will distinguish between bacteria in the three different sensitivity groups. However, it was observed that the greatest effects of Cd on respiration (both stimulatory and inhibitory) occurred among the isolates that demonstrated the greatest sensitivity to Cd. Therefore, the toxic action of Cd toward some bacteria may include specific interactions with the electron transport system, whereas the apparent lack of Cd-sensitive electron transport by other isolates does not necessarily confer Cd resistance.

Publications and professional presentations:

Burke, B. E., and R. M. Pfister. 1986. Cadmium Transport by a Cd^{2+} Sensitive and a Cd^{2+} Resistant strain of Bacillus subtilis. Can. Journ. Bacteriol., in press.

Burke, B. E., and R. M. Pfister. 1986. "Cadmium Resistance and Accumulation by Selected Lake Sediment Bacteria." Abs. Annual Meeting of the American Society for Microbiology.

M. S. thesis:

None

Ph. D. dissertations:

None

SYNOPSIS

Project No. 04 Start: 07/85 (actual)
End: 06/86 (expected)

Title: Effect of Seasonal Water Usage Variations Upon Reservoir Safe Yield

Investigators: Whitlatch, E. E., The Ohio State University, Columbus

COWRR: 05D Congressional District: Fifteenth

Descriptors: water demands, simulation analysis, time series analysis, municipal water, safe yield, Ohio

Problem and research objectives:

Every municipality, rural community, or agricultural water user served by a surface water source must obtain an accurate estimate of the amount of water that it can safely withdraw. The estimated value is called safe yield of the system, and is usually expressed as the rate of constant withdrawal that will cause a water supply shortage to be expected only once in a given number of years (usually 50 years). The assumption that safe yield can be based upon a constant water usage throughout the year may not be justified, and may result in substantial overestimations.

State-of-the-art methods have not been applied systematically to determine the extent of seasonal (monthly) fluctuations in water usage, nor the effect of such fluctuations upon statistical safe yield estimates. Therefore, it is necessary to recognize and deal with these seasonal fluctuations when statistically computing water supply safe yields.

The objectives of the research are (1) to obtain seasonal water use data for communities in Ohio that would be representative of the State, and to summarize and perform statistical tests upon these data in a manner so as to typify the underlying variability; (2) to develop synthetic data generation scheme(s) that would capture the fundamental statistical nature of the seasonal water usage data; and (3) to jointly simulate seasonal water usage and streamflow so as to derive statistical estimates of safe yield under the expected range of seasonal water usage fluctuations. Results can then be presented in a manner showing the expected influence of seasonal fluctuations on safe yield.

Methodology

In the first stage, site visits, phone communication, letters and questionaires were utilized to obtain monthly water use data for all municipal systems with capacitiies of one MGD or more (see tabulation on page 32). Data analysis will be commensurate with obtaining necessary statistics and parameters for use in the generation step (stage 2), as well as in describing seasonal variation and other characteristics of the water use data. The second stage is generation of monthly water usage data. Three possible generation schemes are envisioned: one is the disaggregation process; the second and third approaches are the ARMA and ARIMA models. Detrending is common to both the ARMA and ARIMA procedures, but the deseasonalizing step is conducted differently in the two. The ARIMA approach uses cyclic, and perhaps non-cyclic, differencing to achieve stationarity while the ARMA

approach utilizes a variety of mathematical measures in an attempt to avoid the differencing step. In the third stage, generated monthly use and streamflow are combined in a simulation environment and statistical results are summarized. The streamflow generator found adequate and most conservative will be utilized. The combined usage-streamflow safe yield analysis will be parameterized over the range of seasonal fluctuations found in the data, and over selected ratios of total annual usage to total annual inflow. Results will be compared to safe yield estimates found assuming no seasonal fluctuations.

Principal findings and significance:

Data have been solicited from the 162 municipal water suppliers in Ohio with demand of one MGD or more, and 73 have responded. The data from 29 systems having at least 20 years of continuous data have been stored on the computer (see tabulation on page 32).

Computer plots of the 29 selected records indicate the following, based only on visual evaluation and simple tabulations:

(i) There is a wide range in demand variability (seasonality), with approximately one-half being highly seasonal, one-third being moderately seasonal and the remainder exhibiting low seasonality.

(ii) There is no obvious correlation between degree of seasonality and either system size (MGD) or percent residential.

The significance of these preliminary findings is that they support the underlying premise of this research that consideration of seasonality

is vital for accurate determination of safe yield, and they may not support findings by others that small rural communities have more extreme seasonal fluctuations than do large municipalities.

Publications and professional presentations:

None

M. S. thesis:

None

Ph.D. dissertations:

None (1 Ph.D. participant)

Water Systems That Responded

Name of System	Years of Data	Name of System	Years of Data	Name of System	Years of Data
Adams Co.	--	Galion*	37	OWS, Madison	--
Akron*	26	Gallipolis	2	OWS, Marysville	4
Archbold*	27	Greenville*	24	OWS, Massillon	1
Ashland	18	Hamilton*	25	Piqua*	20
Bedford	--	Kent	--	Port Clinton	10
Belmont Co.*	20	Kenton	2	Reading	17
Berea*	28	Lakewood*	26	Reynoldsburg	9
Bowling Green	--	Lebanon	--	Ross Co.	--
Campbell	--	Lorain*	25	St. Marys*	24
Canton*	20	Lorain Co.	7	Salem	--
Cincinnati*	23	Mahoning Valley*	29	Scioto Co.	--
Circleville	13	Mansfield*	25	Sidney*	20
Clermont Co.	5	Marietta	--	Sylvania	6
Cleveland*	24	Martins Ferry*	30	Tallmadge	--
Cleveland Hts.*	30	Maumee	--	Toledo*	30
Columbus*	29	Medina	--	Twin City	15
Conneaut	4	Miamisburg*	20	Wapakoneta	17
Coshocton	10	Middletown	15	Warren*	27
Delaware*	27	Minerva	16	Washington C. H.	--
Delaware Co.	--	Mingo Junction	--	Westerville*	33
Elyria*	25	Montgomery Co.*	25	Wooster	1
Englewood	16	Mount Vernon	18	WPAFB	10
Erie Co.*	29	Newark	--	Xenia	12
Franklin	--	Norwalk*	27		
East Liverpool	--				

*Indicates city with 20 or more years of data which was selected for further analysis

Systems That Were Polled But Did Not Respond

Alliance	Defiance	Huron	Oakwood	Springfield
Amherst	Delphos	Indian Hill	OA, Ashtabula	Steubenville
Athens	Dover	Ironton	OA, Lee Dist.	Summit Co.
Avon	E. Cleveland	Jackson	OA, Marion	Tate Monroe
Avon Lake	E. Palestine	Lake Co. E.	OA, Tiffin	The Water Assoc.
Barberton	Fairborn	Lancaster	OS, Lew Dist.	Tipp City
Bellaire	Fairfield	Lima	OS, Struthers	Troy
Bellefontaine	Findlay	Lincoln Village	Oregon	Urichsville
Bellevue	Fostoria	Lockland	Orrville	Urbana
Bexley	Franklin Co.	Logan	Oxford	Vandalia
Bryan	Fremont	Loveland	Painesville	Van Wert
Bucyrus	Gahanna	Masury	Perrysburg	Wadsworth
Butler Co.	Gallia Co.	Napoleon	Portsmouth	Wellsville
Cambridge	Girard	New Philadelphia	Ravenna	W. Carrollton
Celina	Greater Moraine	Niles	Riverside	W. Water Subdiv.
Chillicothe	Heath	North Canton	Sandusky	Willard
Cuyahoga Falls	Huber Hts.	North Ridgeville	Shelby	Wyoming
Dayton		Norwood	Shenango	Youngstown
				Zanesville

Note: Response rate was 72/162 = 44%

SYNOPSIS

Project No. 05 Start: 07/85 (actual)
End: 06/86 (expected)

Title: Risk-Benefit Analysis of Annular Disposal of Oil and Gas Brines

Investigators: Hobbs, Benjamin F. and Haimes, Yacov Y., Case Western Reserve University, Cleveland

COWRR: 06B Congressional District: Twenty-first

Descriptors: risk-benefit analysis, *brine disposal, waste disposal wells, Ohio

Problem and research objectives:

Severe problems are associated with the handling of brine wastes from oil and gas wells in Ohio. Of the roughly 160,000 bbls/day of brine produced in the state, less than 20% is disposed of properly. As a result, surface and ground waters supplies are often contaminated.

One controversial disposal method allowed in Ohio is annular disposal. This practice consists of the deposition of brine into the annulus of the production well. Because annular disposal provides but one or two barriers between the brine and fresh water aquifers, it is inherently more risky than deep well injection, which presents at least three.

The first objective of the research is to investigate the risks and benefits of permitting annular disposal. Its benefits are (1) the avoided costs of deep well injection and (2) the secondary benefits of employment and taxes from a financially healthier Ohio oil and gas industry. The risks are the health and financial costs resulting from

possible groundwater contamination. A second objective is to create a computerized methodology that will enable government agencies and private parties to evaluate the risks and benefits of annular disposal in particular regions.

Methodology:

The research consists of five tasks:

1. Estimation of the frequency and severity of brine leaks from annular disposal wells by statistical analysis of actual well test data.

2. Calibration and application of solute transport models for two types of fresh water aquifers in regions where annular disposal takes place.

3. Estimation of the probability that water supply wells of towns and rural homes using those aquifers will be affected by brine spills, using the models developed in tasks 1 and 2 and probabilistic models of the distribution of water wells.

4. Estimation of financial costs of supply contamination, via engineering economic analysis, and the degree of violation of health standards.

5. Estimation of the benefits of annular disposal using engineering economic and econometric analysis.

There are two products of this research: the first, is an assessment of the risks and benefits of annular disposal in two study regions of Ohio. The second, is a computerized methodology which allows government or private users to conveniently undertake tasks 2, 3, and 4 for other study areas.

Principal findings and significance:

During the first year of the project, significant progress was made on all tasks. The results include estimates of the probability of failure of annular disposal, analyses of the risks to water supply for two Ohio aquifers, and an integrated micro-computer based methodology for accomplishing tasks 2 and 3 for any study region.

Task 1: Estimation of Annulus Reliability. The probability of failure of annular disposal wells was estimated using data obtained from the Louisiana Bureau of Conservation, Division of Injection and Mining. This data was the only available in the U.S. from which reliability of annular disposal could be estimated. The data are primarily in the form of results from radioactive tracer surveys conducted annually to check for mechanical integrity.

The probabilities of failure were quantified using maximum likelihood estimation. This standard statistical procedure is based upon a function expressing the probability of observing the sample, which, when maximized, results in estimates of the parameters (or in this case, the probabilities). Maximization was accomplished using a generalized reduced gradient method. In the analysis, the Louisiana

wells were divided into three basic categories. The first contained wells which failed their first mechanical integrity test -- essentially, those which failed at sometime before the first test. In the second category were wells which had never failed a test, and in the third, those which failed in some subsequent year after the start of testing. Two probabilities were estimated:

p = the probability of immediate failure due to faulty installation of the production casing; and

q = the probability per year of failure subsequent to well completion.

The resulting probabilities of failure are p = 0.0 and q = 0.011/yr. In words, (1) given that a well has been operating for several years, the first year seems to have no additional risk of failure than any other year (p = 0) and (2) the probability per year of well is about 1%. Work is underway to establish confidence intervals for these results.

Typical values of brine loss in Louisiana, given a failure of the annulus, were found to be between 5% and 20% of the amount injected in the annulus, depending on the permeability of the receiving geologic medium.

Tasks 2 and 3: Calibration of Solute Transport Model, Population Distribution Estimation, and Estimation of Risks of Water Supply Contamination. In these tasks, a USGS two-dimensional solute transport model has been interfaced with a computer program called "Risk Impact

from Solute Contamination" or "RISC". The object of these models is to estimate probability distributions for numbers of water wells and town water supplies contaminated due to failure of annular disposal. These impacts are uncertain for several reasons. Among these are the randomness of the annulus failures and their severities, and uncertainties in the number of water supplies that might be affected by a given failure. RISC explictly considers these uncertainties. The models were applied to two Ohio aquifers: the buried valley of the Muskingum River in Coshocton County and the Black Hand Sandstone Aquifer in Vinton County.

To apply the models, the following modeling steps are undertaken:

1. A preprocessor to the solute transport model is used interactively to input and modify the geohydrologic parameters used by the model.
2. The solute transport model is used to generate an impulse response function, showing how solute concentrations respond over space and time to a unit input at a specified time and place. The use of such a function in the subsequent steps presumes that the system behaves linearly, which is reasonable if brine inputs are small compared to groundwater flow rates.
3. RISC takes the impulse response functions and uses them to calculate the response of the aquifer to annulus failures of various durations and severities for a single oil/gas well. The durations and severities are described by

probability distributions which are a function of, among other things, the frequency of well inspection.

4. RISC then calculates, for each failure, the spatial area for which the concentration of any contaminants (TDS, chlorides, heavy metals, benzene) exceeds prespecified water standards any time over a given time horizon.

5. For each failure type, RISC then calculates conditional probability distributions of numbers of rural wells and town water supplies contaminated. This is based on the assumption that the numbers of wells and towns within a given area are distributed randomly according to Poisson distributions. Then, given the probability of each failure type, the unconditional probability distributions for a single oil/gas well of contaminated rural wells and town water supplies are calculated.

6. The overall probability distributions of impacts are then calculated for a set of N annular disposal wells, where N is the number of such wells in the study region. These distributions describe the risk of annular disposal for the aquifer in question.

These models were applied to two aquifers representing a range of geohydrologic conditions. The Black Hand Sandstone has meager water well yields, small hydraulic gradients, and slow groundwater velocities. In contrast, the Muskingum River Valley has very

productive wells, moderate gradients, and high flow rates. Most of the geohydrologic parameters for these sites were obtained from actual observations from pump tests. The analyses yielded estimates of a small, but finite risk in the Black Hand Aquifer and no risk in the buried valley. The estimated risk was smaller for the buried valley because brine leaks were estimated to be small (on the order of 1 bbl/day) and the higher groundwater velocities there diluted the brine to levels well below public health standards. However, significant contamination might still occur within the immediate vicinity (50 feet or less) of an annular well; this possibility was not considered by the transport model because of the cell size (at least 50' by 50') used.

Another analysis showed the tradeoff between risk of water supply contamination and frequency of radioactive tracer testing of annular disposal wells.

Task 4. Estimate financial costs of contamination and the degree of violation of health standards. Interviews and literature surveys were conducted to obtain estimates of the financial costs of contamination, including damages to appliances and property values and the expense of new water supplies.

Task 5. Estimation of benefits of annular disposal. Estimates of the cost of deep well injection have been obtained, and economic models are being formulated to estimate the impact of banning annular disposal upon the Ohio oil and gas industry.

Publications and professional presentations:

"Risk Analysis of Annular Disposal of Oil and Gas Brines," Division of Oil and Gas, Ohio Department of Natural Resources, Columbus, OH, July 23, 1986.

M. S. thesis:

Carl-von Patterson, "Risk Estimation of Annular Disposal of Oil and Gas Brines," Case Western Reserve University, Cleveland, OH, July 1986.

Ph. D. dissertations:

None

INFORMATION TRANSFER ACTIVITIES

A series of tasks were continued or initiated to transfer and to disseminate information developed by researchers affiliated with the Water Resources Center to a wide range of State, Federal, County and Municipal agencies; to the private sector; to the academic community and to private citizens throughout Ohio.

Ohio Water Resources Directories

The Water Resources Center has completed and published a directory of water related agencies within the state of Ohio. A directory of the international, federal, state, interstate, regional and local water agencies was published about ten years ago by the Water Management Association of Ohio. There have been several revisions in the governmental agencies and in personnel since the original directory was published, and a current one was sorely needed. The assistance and support of the principal water-related state and federal agencies and of the Water Management Association of Ohio will be sought to help distribute the directory.

The Water Resources Center is also planning the development and distribution of a directory of the scientific expertise available in all areas of water resources research at the Universities within the State of Ohio. A questionnaire has been prepared and printed and will soon be distributed to all the researchers and research

administrators at the forty-two Universities and colleges that are known to have demonstrated expertise in some field of water resources research. Key personnel at these Universities will be asked to circulate the questionnaries on their own campus to develop a wide response, but no extensive follow-up calls are planned to attract responses. When the questionnaires are returned to the Water Resources Center, the information will be keyed into our computer and the final directory will be prepared. Funds will be sought from the State water related agencies and the Universities to help defray the costs of publication and distribution of this directory.

Water Luncheon Seminars

The Water Resources Center continued to co-sponsor a bi-monthly Water Luncheon Seminar Program for the water resources community in Central Ohio. This program, which was developed cooperatively with the Ohio Department of Natural Resources (ODNR), the Ohio Environmental Protection Agency (OEPA), the Soil Conservation Service (SCS), the District Office of the United States Geological Survey (USGS), and the Agricultural Engineering Cooperative Extension Service of The Ohio State University, continues to attract about seventy water resources professionals from Federal, State, County and Municipal Agencies, the private sector, and the academic community, to a forum to discuss current state, federal and local water policy issues, problems, programs and research results. In addition to providing speakers for one meeting a year, the Water Resources Center maintains the mailing list and produces and distributes the announcements for this program.

Listed below are the speakers and their topics that were presented during this year's meetings.

WATER LUNCHEON SEMINAR, FY 1985

Date	Speaker	Topic
9/9/85	Ken Schultz, Chief Office of Emergency Response Ohio Environmental Protection Agency	Office of Emergency Response
11/26/85	Pete Finke Ohio Department of Natural Resources	Floods and Flood Plain Management
01/07/86	Phillip Case, Marion Co., Health Dept. Vanessa Tolliver, ODNR Russ Stein, Groundwater, OEPA	Ground Water Quality Problems and Programs Panel Discussion
03/11/86	Janet Hren Hydrologist, USGS District Office	Summary of Ohio's Water Quality Data
05/13/86	Joseph Neidhardt, Asst. Exec. Dir. Development Committee for Greater Columbus	Your Infrastructure -- Your Problem

Consultation and Collaboration Activities

The Center's Director has continued to meet with the leading water resources officials in the state for the purposes of consultation and collaboration to identify the major water problems and the research needs of the state and region; to share information on current water management and policy issues; to seek continued support for our water research program and to disseminate the information and technology developed through this program and others at the universities throughout the State and Region.

The Director is the Lead Delegate to the Universities Council on Water Resources (UCOWR) and is a member of the Board of Directors; he is Past-Chairman of the National Association of Water Institute Directors (NAWID) and is a member of the Council of Representatives; he serves on the Water Programs Public Advisory Group to the Ohio Environmental Protection Agency and is a member of the Toxics Technical Advisory Committee; and he is a member of the Ohio Inter-Agency Water-Use Data Coordinating Committee for the Ohio District of the U. S. Geological Survey. In addition to these activities, the Director has assisted in developing the organization of the newly created International Water Resources Center at Central State University, a historically black university.

The Ohio State University recently became a Charter Member of the newly formed Ohio River Basin Research and Education Consortium, and the Director has served as a member of the Board of Trustees of that organization since November, 1985.

Water Resources Center Library

The Water Resources Center has maintained a library of water resources related publications since its establishment in 1965. Recently, the Center's holdings were merged with those of the Center for Lake Erie Area Research (CLEAR). The Water Resources Center provided the space for this merged library while CLEAR provided the staff to catalogue the material. This year the Water Resources Center also provided support for the operation of the library.

COOPERATIVE ARRANGMENTS

Program Development

A program announcement that included the research priorities identified for the major water problems in the Great Lakes, Upper Mississippi and Ohio River Basins by the Water Resources Research Institutes in the region was sent to research administrators and qualified faculty investigators at forty private and public colleges and universities throughout Ohio on December, 1984.

The announcement also contained some preliminary guidelines for the submission of pre-proposals that had been discussed at a meeting of the Council of Representatives of the National Association of Water Institute Directors (NAWID) with the Assistant Chief Hydrologist for Operations in the Geological Survey and his staff in Reston, Virginia on October 28, 1983.

The complete distribution list for this mailing contained over 250 names. In addition to this general mailing, separate letters were sent to the Presidents of the two Historically Black Universities in the State encouraging them to have their faculty participate in the Program.

Evaluation/Selection Procedures

Twenty-one pre-proposals from seven universities and colleges throughout the state were submitted for evaluation and consideration. These pre-proposals were subjected to a review by all of the members of the Water Resources Center's Advisory Committee. In addition, the twenty-one pre-proposals were distributed to the various divisions within the three principal state and federal water-related agencies in the State by the representatives of these agencies who serve on the Advisory Committee, requesting that the divisions review them. The three agencies included in this evaluation were the Ohio Department of Natural Resources; the Ohio Environmental Protection Agency; and the District Office of the United States Geological Survey.

The results of these reviews were presented at a meeting of the Advisory Committee where this panel selected seven of the pre-proposals and instructed the Center's Director to request fully developed proposals from the investigators for the Committee's further consideration.

All seven of the selected proposals were developed more fully and were re-submitted for consideration. The proposals were subjected to a technical review by at least three qualified evaluators selected by individual members of the Water Resources Center's Advisory Committee. Many of these evaluators were from state and federal agencies and from universities other than The Ohio State University.

The results of these reviews were presented at a meeting of the Advisory Committee,and this panel ranked all seven of the proposals in the order they felt would best meet the needs and objectives of the Water Resources Center's program. The Advisory Committee then instructed the Center's Director to incorporate the four highest ranked proposals into the FY 1985 Program and to develop a project for information transfer for the Center.

The membership list of the Water Resources Center's Advisory Committee, which includes representatives from five colleges and eleven departments at The Ohio State University and the three representatives of the principal water-related state and federal agencies, are included at the end of this segment of this Report.

Regional Cooperative Initiatives

As in the previous years, the four projects selected for this program were compared with the synopses of the projects included in the programs of the other Water Resources Institutes in the Great Lakes, Upper Mississippi and Ohio River Basin Region to ensure that there was no duplication of efforts in the Region's research programs.

WATER RESOURCES CENTER ADVISORY COMMITTEE

COLLEGE OF ENGINEERING

1. Dr. Vincent T. Ricca
   Civil Engineering

2. Professor Edwin E.Smith
   Chemical Engineering

3. Dr. Robert C. Stiefel
   Director
   Water Resources Center

4. Dr. Brian Wilde
   Metallurgical Engineering

School of Architecture

5. Dr. Steven I. Gordon
   City of Regional Planning

COLLEGE OF BIOLOGICAL SCIENCES

6. Dr. Robert M. Pfister
   Microbiology

7. Dr. Jeffrey Reutter
   Lake Erie Programs

8. Dr. William DeMott
   Zoology

9. Dr. David Culver
   Zoology

10. Dr. F. Joseph Margraf
    Ohio Cooperative
    Fisheries Unit

COLLEGE OF MATHEMATICAL AND PHYSICAL SCIENCES

11. Dr. Garry McKenzie
    Geology and Mineralogy

COLLEGE OF AGRICULTURE

12. Dr. Terry J. Logan
    Agronomy

13. Dr. Melville Palmer
    Agricultural Engineering

School of Natural Resources

14. Dr. Robert L. Vertrees
    Resources Management

COLLEGE OF MEDICINE

15. Dr. John R. Wilkens, III
    Preventive Medicine

ADMINISTRATIVE MEMBER

16. Mr. McIver C. Woody
    Ohio State University
    Research Foundation

OHIO ENVIRONMENTAL PROTECTION AGENCY

17. Dr. John F. Estenik

OHIO DEPARTMENT OF NATURAL RESOURCES

18. Dr. William Mattox

UNITED STATES GEOLOGICAL SURVEY

19. Mr. Steven Hindall
    District Chief

Program Management

At least once each quarter, the Director contacts the Principal Investigator on each research and information transfer project to discuss progress made during the quarter and to discuss the next quarter's plan of activities. At this same meeting budget details are reviewed and discussed, and necessary operating and reporting procedures to the Water Resources Center and to the Ohio State University Research Foundation's business office are described.

Progress Reports or Completion Reports will be prepared for each Project by the Principal Investigators and will be used by the Program Director to prepare the Program Final Report.

All of our investigators are urged to publish the results of their findings in the technical literature of their major disciplines and in other journals that are appropriate to the topic of their research. They are also encouraged and invited to present their findings at the Water Luncheon Seminar that is a part of the technology transfer activities of the Center.

The manuscripts that constitute the project completion reports are first reviewed by the Director of the Water Resources Center. As needed, the Director seeks the advice and council of appropriate state, federal, and university scientists for methods of enhancing the value of the technical completion reports to the water-related community in the state and in the region.

TRAINING ACCOMPLISHMENTS

The following tabulation shows, by fields of study and training levels indicated, the numbers of individuals participating in projects that were financed in part with this grant.

Training Category	Training Level				
		Graduate			
	Undergraduate*	Master's Degree*	Ph.D. Degree*	Post-Ph.D.*	Total*
Engineering					
- Chemical		2		1	3
- Civil	2		1		3
- System Engr.	2	2			4
Biological/ Natural Science					
- Biology			1		1
Social/ Institutional Science					
- Resource Planning		1			1
TOTALS	4	5	2	1	12

*Insert the number of individuals participating in the projects financed by the award.